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LEVEL II

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18. SUPPLEMENTARY NOTES

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Drawbar horsepower
Dynamometer
Fuel consumption (full load)
Soft-soil mobility
Vehicle, amphibious
Vehicle, tracked
Vehicle, wheeled

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Describes procedure for evaluating vehicle power available for acceleration, towing, or hill climbing. Defines drawbar pull. Includes procedures for hard-surface, soil, and water tests. Discusses vehicle preparation, instrumentation method of computing results, data reduction and presentation. Establishes curves for comparing performance with similar vehicles and for predicting gradeability. Applicable to wheeled, tracked, and amphibious vehicles.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-101
*Test Operations Procedure 2-2-604
AD No.

18 July 1980

DRAWBAR PULL

Page

1. SCOPE. This TOP describes the procedures for determining the drawbar-pull characteristics of wheeled and tracked vehicles on hard-surfaced roads and in soft soils, and of amphibious vehicles in water.

Drawbar pull provides a measure of the reserve power available to a vehicle (in excess of that required for vehicle propulsion on a level road) for acceleration, towing, or hill climbing. Vehicles are tested for drawbar pull to establish performance curves that can be used for evaluations and comparisons with similar vehicles. These data also serve to predict gradeability when no facilities are available for determining slope performance at a desired gradient (TOP 2-2-610).

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

ITEM	REQUIREMENTS
Mobile Field Dynamometer	As described in TOP 2-0-005.
Test Courses	Selected from those described in TOP 1-1-011 to satisfy test directive.

*This TOP supersedes TOP 2-2-604, 19 November 1975.

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2.2 Instrumentation.

ITEM	MAXIMUM ERROR OF MEASUREMENT*
Force-measuring device	±0.5% of full-scale range
Vehicle speed-measuring device (calibrated fifth wheel with speed indicator)	±0.2 km/hr, or ±0.2 mph
Tachometers (engine and wheel or sprocket speeds)	±0.5% of full-scale range
Temperature-measuring devices	±1°C
Pressure-measuring devices (oil, fuel, etc.)	±1% of full-scale range
Fuel consumption measuring device	±2% of full-scale range

*Values may be assumed to represent ±2 standard deviations. Thus, the stated tolerances should not be exceeded in more than 1 measurement out of 20.

3. PREPARATION FOR TEST.

3.1 Test Vehicles. Maintenance and service operations are performed to insure that the vehicle is in condition for optimum performance, with particular attention being given to the engine, transmission, and running gear. A check is made to insure that the proper grade and quantity of lubricant have been used. Unless otherwise specified, the vehicle is loaded with its normal payload or combat weight. Vehicle characteristic data are collected in accordance with TOP/MTP 2-2-500.

3.2 Instrumentation. The vehicle is instrumented to determine the drawbar pull, engine speed, road speed, and track or wheel speed of the vehicle and to monitor (as applicable) the pressures and temperatures of the engine and transmission oil and fuel and cooling systems. The instrumentation commonly used consists of a mobile field dynamometer, an engine tachometer, a calibrated fifth wheel with a speed indicator, sprocket or wheel tachometers, and the appropriate pressure gages and thermocouples. When full-load fuel consumption is measured as part of this test, additional instrumentation is required as described in TOP 2-2-603.

4. TEST CONTROLS.

a. All safety SOP's are observed throughout test operations.

b. Correct levels of lubricant, hydraulic fluid, coolant, etc., are maintained throughout the tests.

c. Vehicles are operated until their normal operating temperatures are reached before initiating each test.

5. PERFORMANCE TESTS.

5.1 Drawbar Pull on Hard Surfaces.

5.1.1 Method. Conduct this test with the test vehicle towing a mobile, field dynamometer by means of an instrumented drawbar over a dry, level, hard surface. The available power at the test-vehicle pintle is measured in as many gear combinations as possible over the speed range of the vehicle at full throttle and full load, at discrete points in the normal operating speed range of the engine. Wheel or track-sprocket speed is also measured and recorded for use in computing the percentage of slip. Measurements are made at sufficient increments of road speed, including vehicle stall when possible, to delineate performance curves (5.1.2 below) and to provide an evaluation of full-load fuel consumption (TOP/MTP 2-2-603). Engine and transmission oil and cooling system pressures and temperatures are recorded, if required.

a. Drawbar pull (DBP) for vehicles with direct mechanical transmissions may be computed for those gear ranges that cannot be measured safely or accurately in field testing because of insufficient traction or high speeds. The calculations are based on the measured pull in a lower gear at a specific engine speed, the overall gear ratios in the ranges being considered, and the measured resistances to towing (TOP 2-2-605) at the road speeds. On this basis and at the same engine speed, the approximate DBP is computed using the following formulas:

Computing for higher gear:

$$DBP_2 = \left(DBP_1 + R_1\right) \frac{OGR2}{OGR_1} - R_2 \qquad (1)$$

Computing for lower gear:

$$DBP_1 = \left(DBP_2 + R_2\right) \frac{OGR1}{OGR_2} - R_1 \qquad (2)$$

where:

DBP_1 = Drawbar pull (kilonewtons)(pounds) in lower gear

DBP_2 = Drawbar pull (kilonewtons)(pounds) in higher gear

R_1 = Resistance to tow (kilonewtons)(pounds) at road speed* for DBP_1

R_2 = Resistance to tow (kilonewtons)(pounds) at road speed* for DBP_2

OGR_1 = Overall gear ratio for lower gear

OGR_2 = Overall gear ratio for higher gear

*Road speed for the unknown DBP value is computed using one of the following formulas:

$$S_2 = S_1 \times \frac{OGR_1}{OGR_2} \qquad (3)$$

$$S_1 = S_2 \times \frac{OGR_2}{OGR_1} \qquad (4)$$

where:

S_1 = Road speed for DBP_1

S_2 = Road speed for DBP_2

Similar DBP calculations can be made for torque converter type transmissions using converter speed ratios.

b. For tracked vehicles with any type of fluid coupling (e.g., torque converter), the maximum pull in the lowest gear range under conditions of vehicle stall (i.e., no forward motion) may be required. At times it may be necessary to tie down the tracks of the test vehicle to obtain this pull without loss of traction. Maximum pull may also be obtained by measuring the stall pull in a higher gear and then computing the lower gear value as follows:

$$DBP_1 = DBP_2 \left(\frac{OGR_1}{OGR_2} \right) \quad (5)$$

5.1.2 Data Required.

a. Curves, as shown in Figures 1 and 2. Values for engine speed, vehicle speed, and drawbar pull. Values for track or wheel slippage and drawbar power obtained through computations using the test data and the following formulas:

$$\text{Percent Slip} = \frac{C-A}{C} \times 100 \quad (6)$$

where:

A = Actual vehicle road speed, km/hr

C = Computed theoretical or no-slip road speed, km/hr

$$= \frac{\text{Wheel or sprocket speed, rpm} \times \text{rolling distance, m/rev}}{16.7} \quad (7)$$

NOTE: For customary units, use mph instead of km/hr, ft/rev instead of m/rev and 88 instead of 16.7.

Drawbar Power:

$$KW = \frac{\text{Road speed (km/hr)} \times \text{drawbar pull (kN)}}{3.6} \quad (8)$$

NOTE: For customary units, use mph instead of km/hr, lb instead of kN and 375 instead of 3.6 to give drawbar horsepower.

b. Fuel temperature (entering the engine).

c. Fuel consumption.

d. Critical component pressures and temperatures.

Vehicle:
Engine Model and Serial No.:
Transmission Model and Serial No.:
Fuel Type:
Vehicle Weight:
Date of Test:
Type of Soil or Operating Surface:
Average Soil Moisture Content:

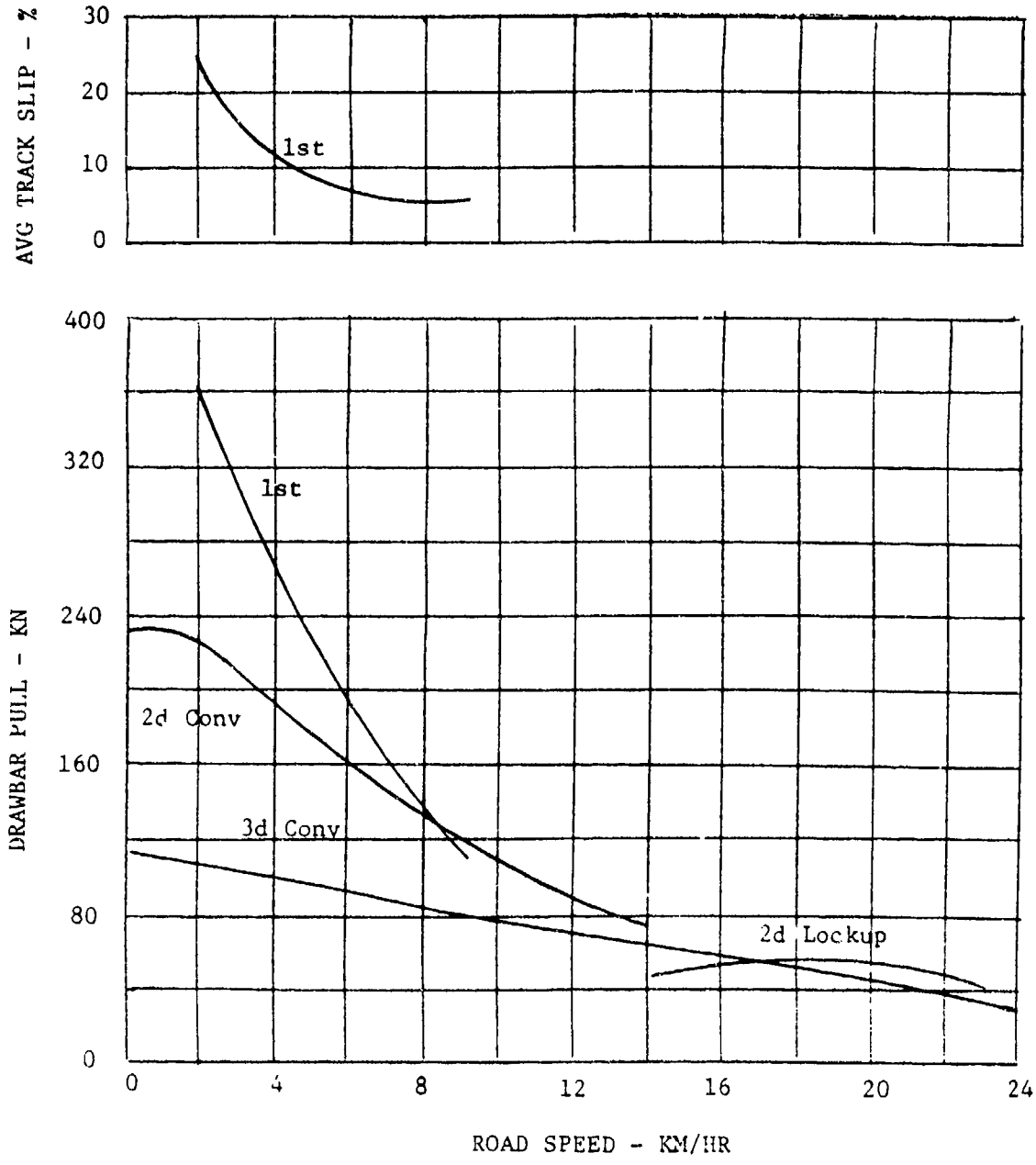


Figure 1. Drawbar-Pull Characteristics.

Vehicle:
Engine Model and Serial No.:
Transmission Model and Serial No.:
Fuel Type:
Vehicle Weight:
Date of Test:
Type of Soil or Operating Surface:
Average Soil Moisture Content:

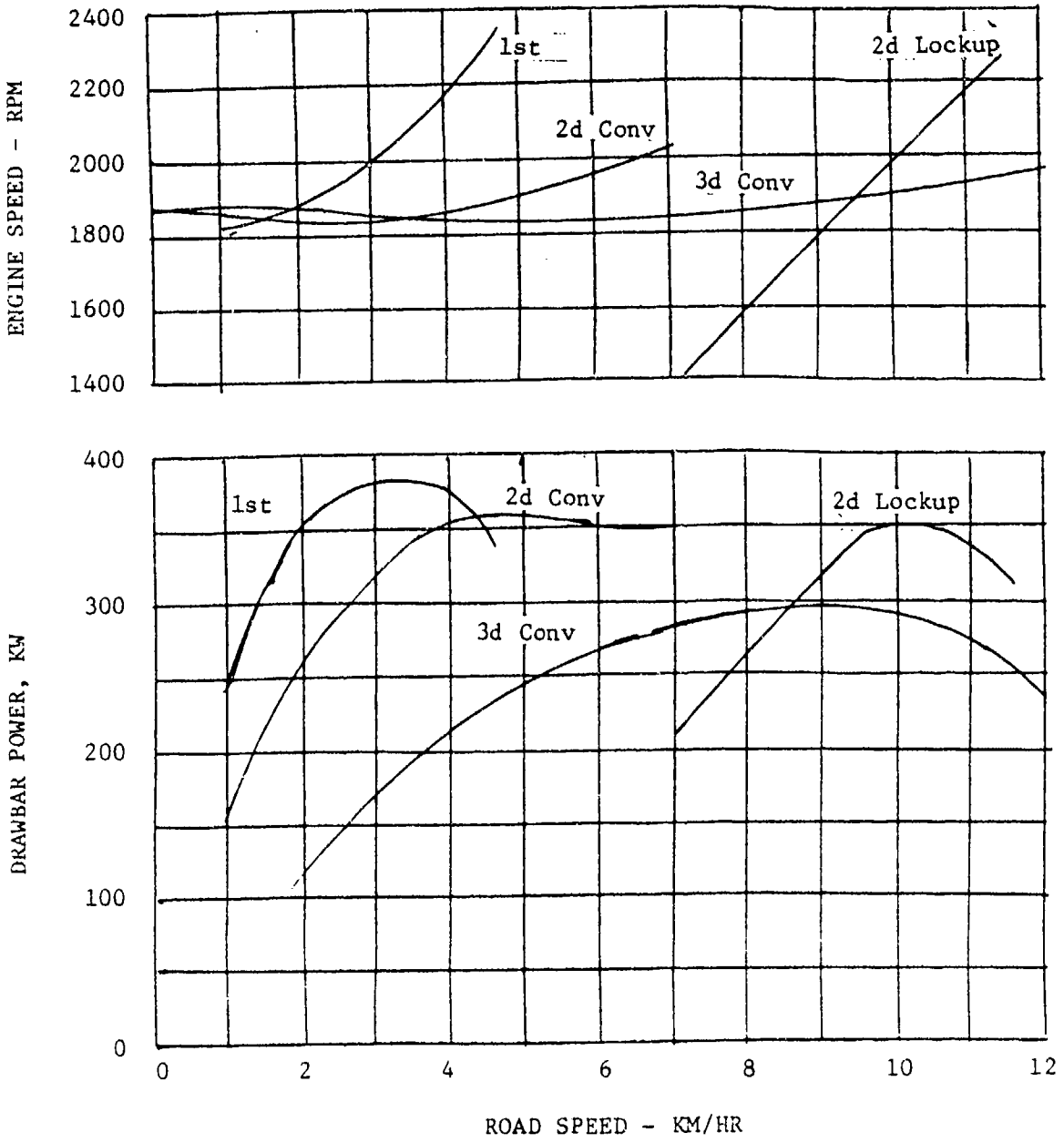
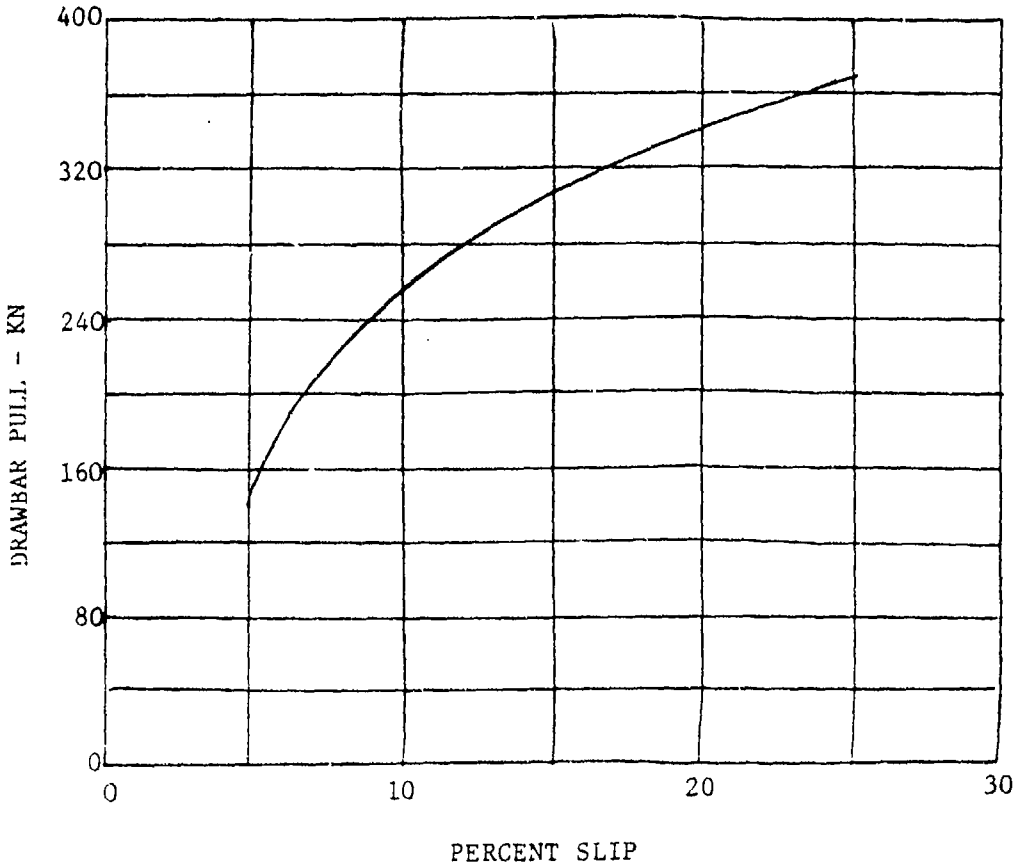


Figure 2. Drawbar Power Characteristics.


400
320
240
160
80
0
0
10
20
30
DRAWBAR PULL - KN
PERCENT SLIP

5.2 Drawbar Pull in Soft Soil.*

5.2.1 Method. Conduct this test in the same manner as the hard-surface drawbar-pull test except that the mobile field dynamometer is towed over level, soft soil tilled to a specified depth. The soil condition is determined and recorded as described in TOP/MTP 2-2-619.

5.2.2 Data Required. Curves (Figures 1 and 2) similar to those used to present hard-surface test results (Paragraph 5.1.2). Drawbar pull versus slip as shown in Figure 3. Values for this curve can be extracted from the curves of Figure 1.

Figure 3. Drawbar Pull Versus Slip.

*This subtest is not essential to every test program, but may be conducted at the discretion of the evaluator.

5.3 Drawbar Pull in Water.*

5.3.1 Method. Measure drawbar pull for amphibious vehicles at various speeds in water by towing a boat (or another amphibious vehicle) in reverse propulsion to the extent necessary for "loading" the test vehicle at the various test-vehicle speeds. The towed item is thus comparable with the dynamometer "load" towed by wheeled or tracked vehicles on land. Care must be exercised to insure that the depth of water is sufficient to give true values (TOP/MTP 2-2-501). Drawbar pull, engine speed, and propellant-device speed are recorded for vehicle stall and for various speeds in water.

5.3.2 Data Presentation. Test results are presented in the form of curves indicating drawbar pull and engine speed for vehicle stall and for various speeds in water.

5.4 Bollard Pull Test.

5.4.1 Method. Conduct this test in water with the floating vehicle moored to a bollard or some other rigid shore structure. The mooring line includes a tension dynamometer and is located directly above and horizontally in line with the propeller shaft or line of thrust.

If the vehicle has rudders, set them on center. Engines are operated in forward gear for 5 minutes at each increment of engine speed up to and including the maximum engine rpm. Gage and instrument readings are taken, including engine and transmission oil and cooling system pressures and temperatures at the end of each engine-speed period. A record is kept of gage and instrument readings, and dynamometer readings, at each specified engine speed.

For multiple-propulsor amphibians each propulsor should be tested independently with the mooring line directly above and horizontally in line with the line of thrust of each propulsor.

This test is also applicable to various other watercraft as described in TOP 9-2-251.

5.4.2 Data Required.

a. Gear range.

b. Pressure and temperature of transmission oil and cooling system.

*See footnote on page 7.

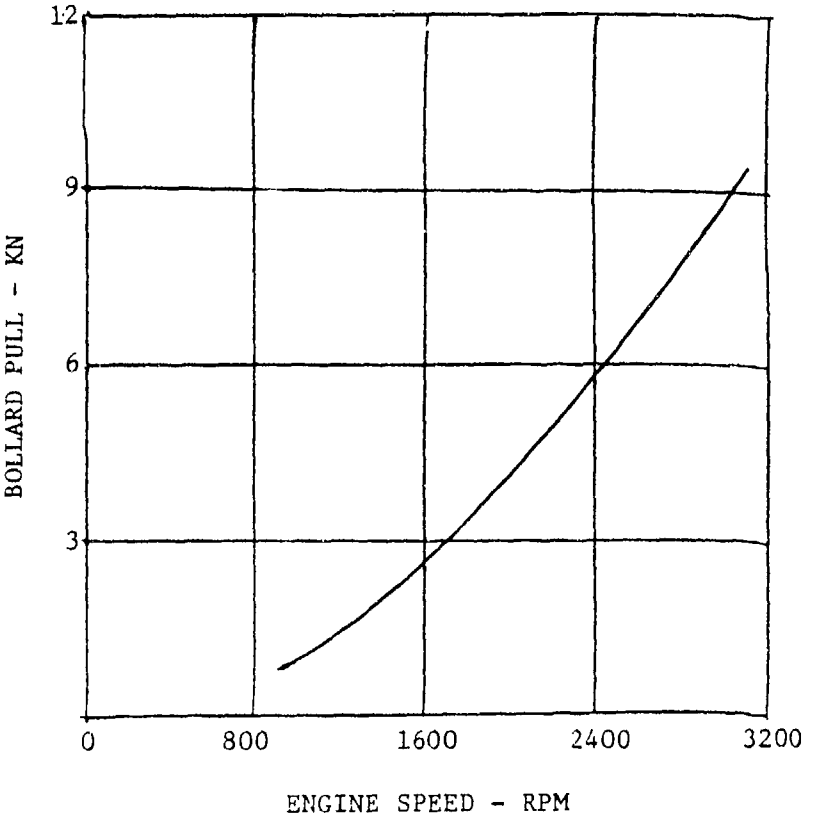


Figure 4. Bollard Pull Characteristics.

6. DATA REDUCTION AND PRESENTATION. Present data in table and graph form as shown in Figures 1 through 4.

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